Solar Plants, Trackers and CPV -- More Solar kWh, at Distributed Scale

ACC EPS Workshop April 5, 2004

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APS Technology Development

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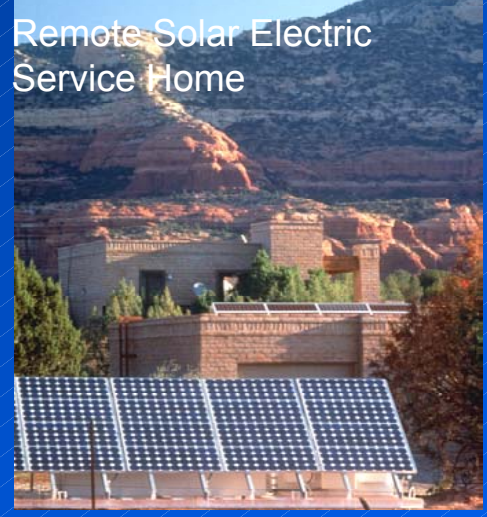
Developing Solar Applications


Carol Spring Mountain Telecom


Remote Solar Electric Service Home

- Off-grid generator replacement with PV-battery-generator hybrids
  - fifty homes and ranches, four large hybrid systems
- Grid-tied 100+ kW, and 2+ kW customer-site PV, in communities across the state
  - diversity & visibility for public awareness and experience
- EPS is incentive for faster pace and higher productivity
  - Prescott Airport 5 MW site established to improve efficiency and lower costs


Scottsdale Water Campus


Glendale Airport

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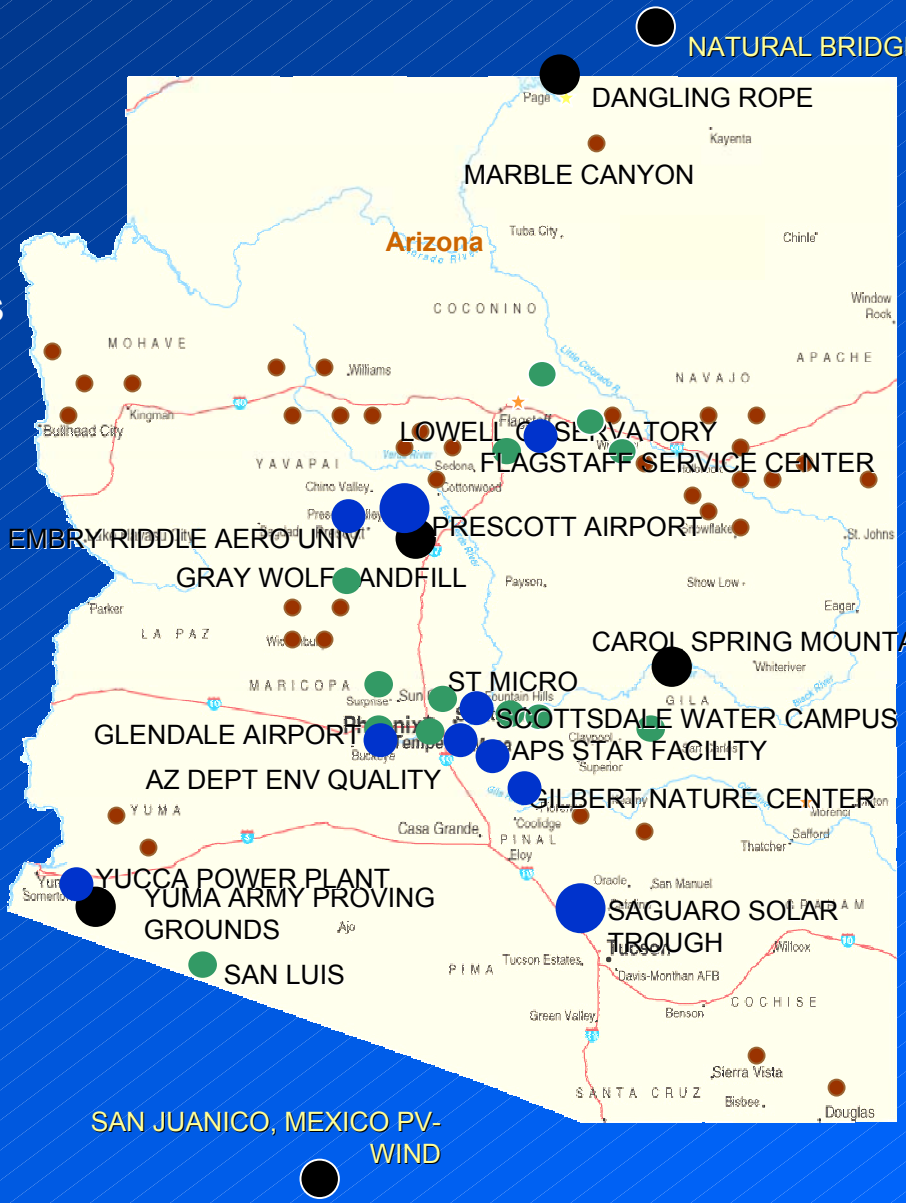
APS Solar Sites

- Over 50 Small PV Hybrid homes & ranches
- Four Large PV Hybrids, plus services to others
- Twenty Rooftop & Customer-Site PV
- Ten 100 kW to MW-scale PV plants

Plus several non-solar projects -- Biomass, Wind, and Hydrogen Fueling Station



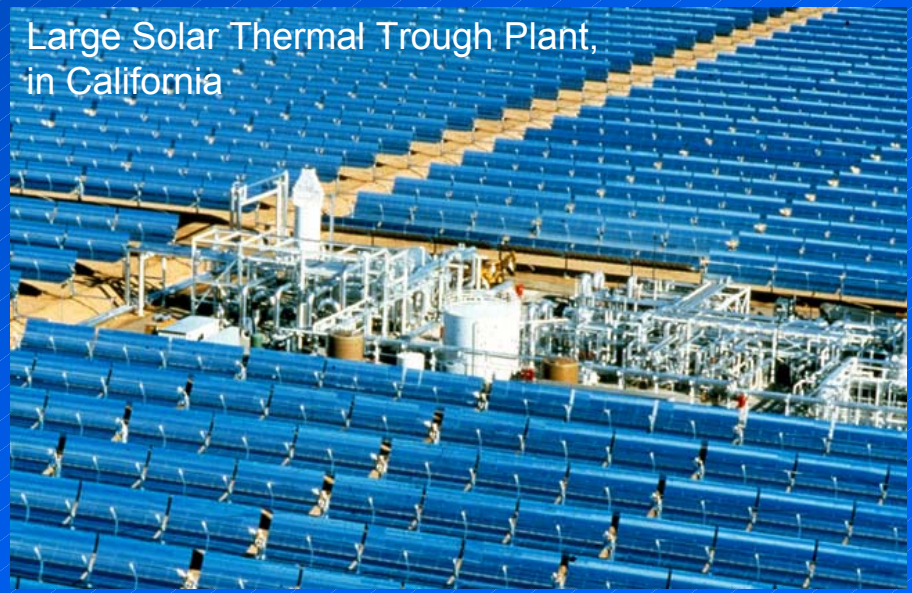
- Flagstaff
- Tempe STAR
- Glendale
- Gilbert
- Yuma
- Embry
- Scottsdale
- ADEQ
- Prescott
- Saguaro
- More...

Variety of Solar Installation Options Now Exist

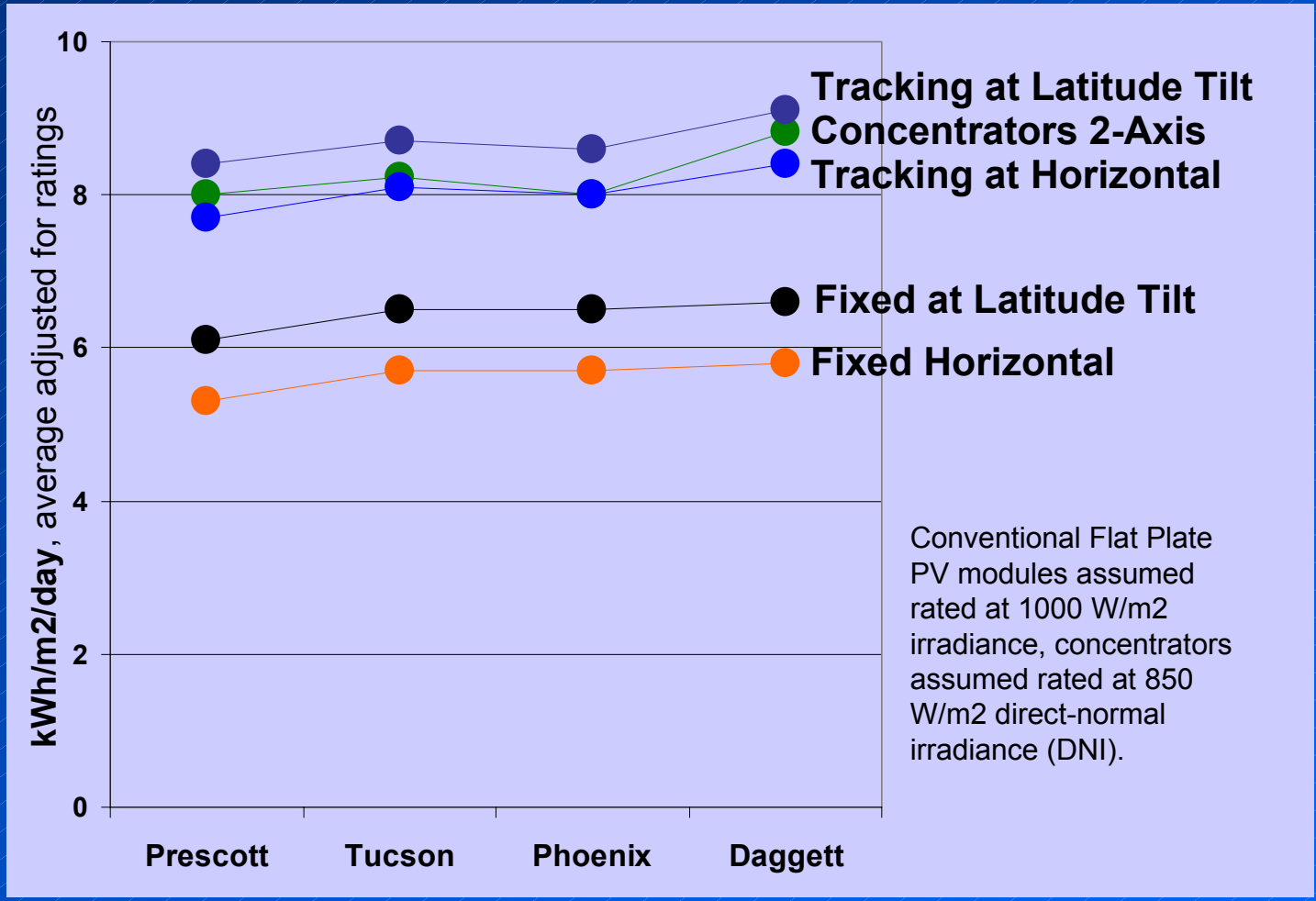

Rooftop Tilted PV,
at Tempe Recycling Center


Tracking and Concentrators,
at STAR in Tempe


Tracking PV,
at Embry Riddle

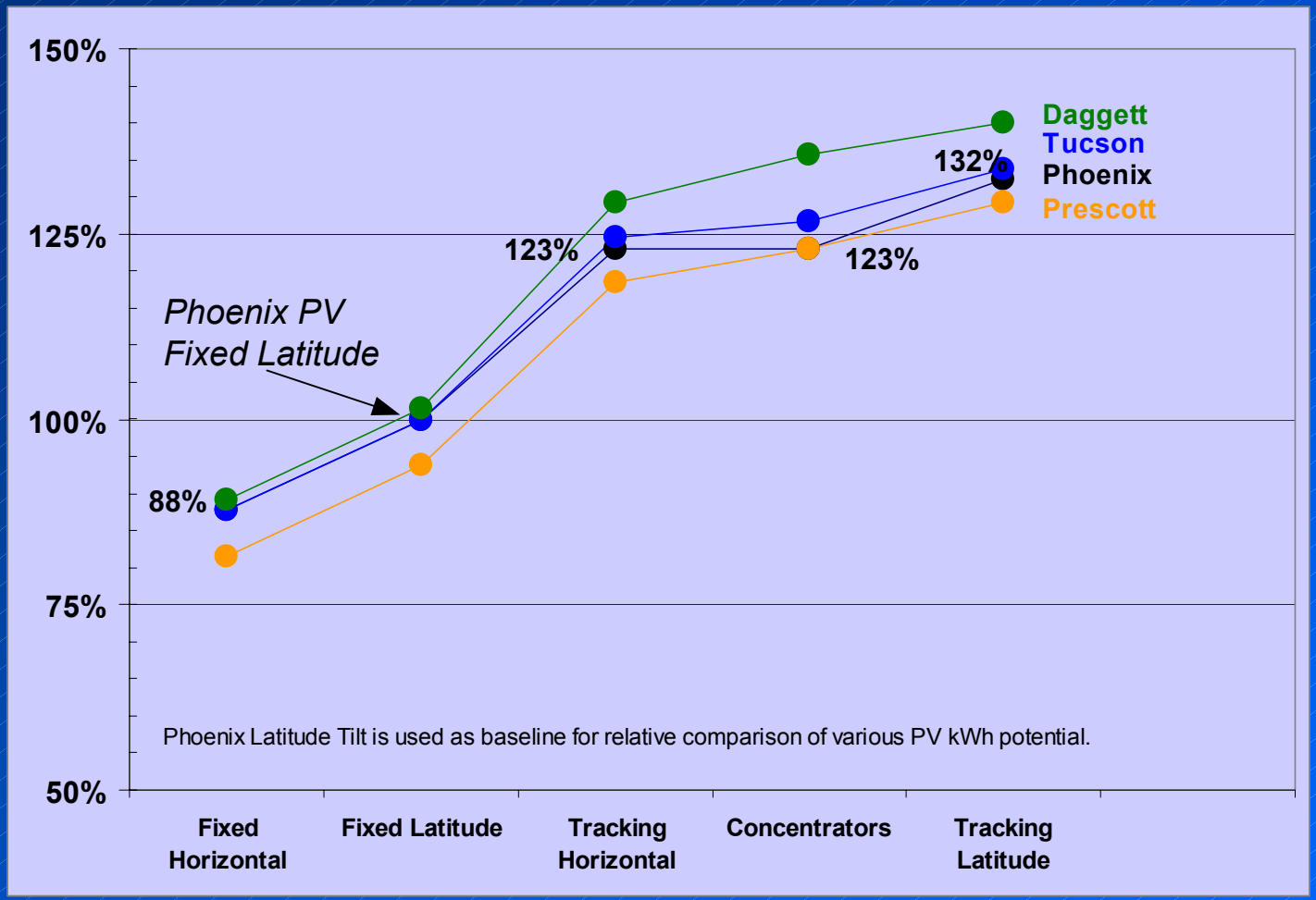

Large Solar Thermal Trough Plant,
in California

Solar Resource Varies with Location & Design



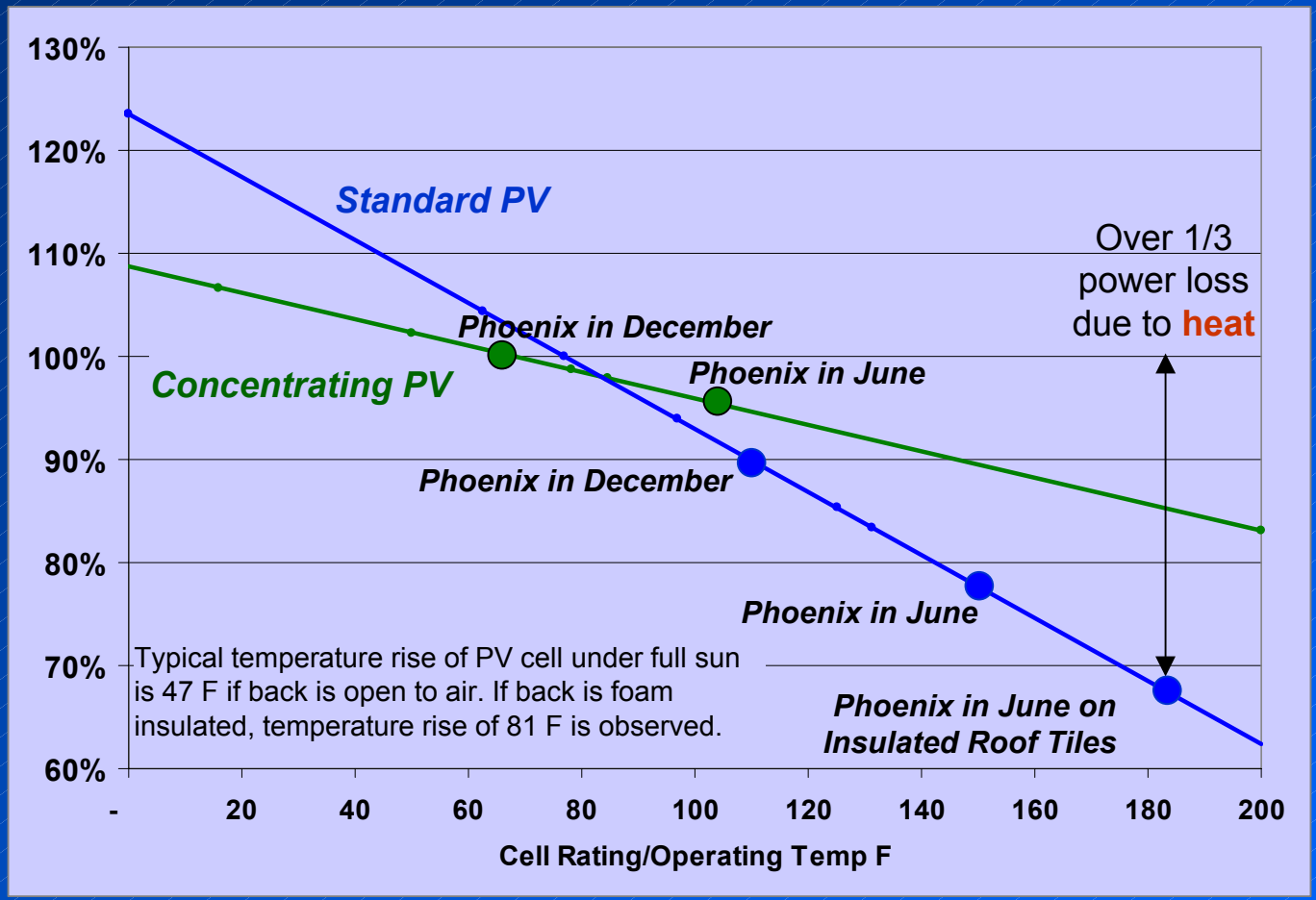
- Annual daily average solar resource, data from NREL Redbook

Resource Trends by PV Location and Type



- More energy output from more exposure to the sun

Temperature Effects on PV



- PV output decreases with heat -- better when cool
- CPV is less affected by temperature

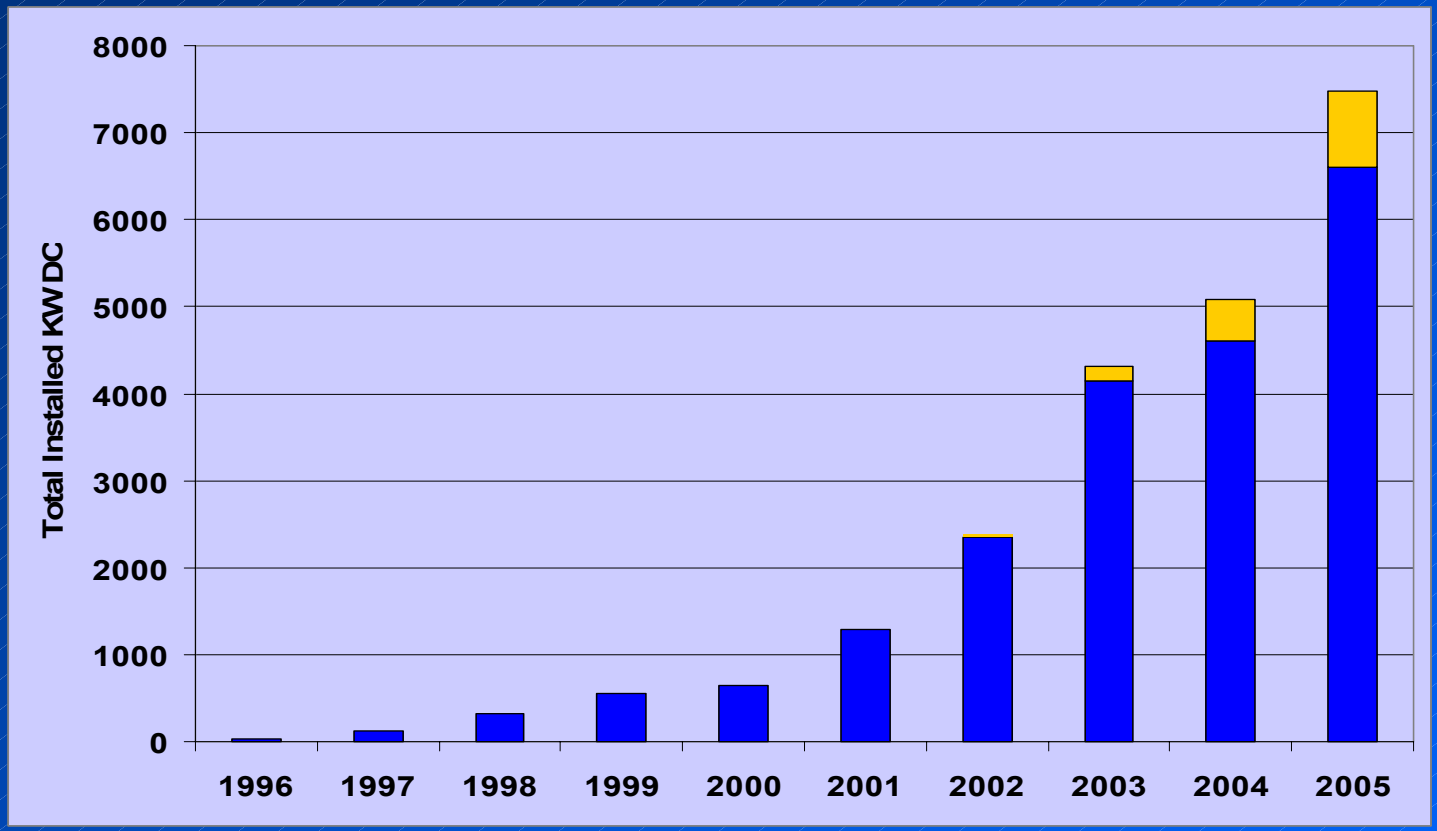
APS Prescott Airport Solar Site

- 2,200 kW currently installed, of 5 MW planned
- Includes large tracking array, and large CPV system
- Made acceptable use of land buffer around airport

Arizona Contributions

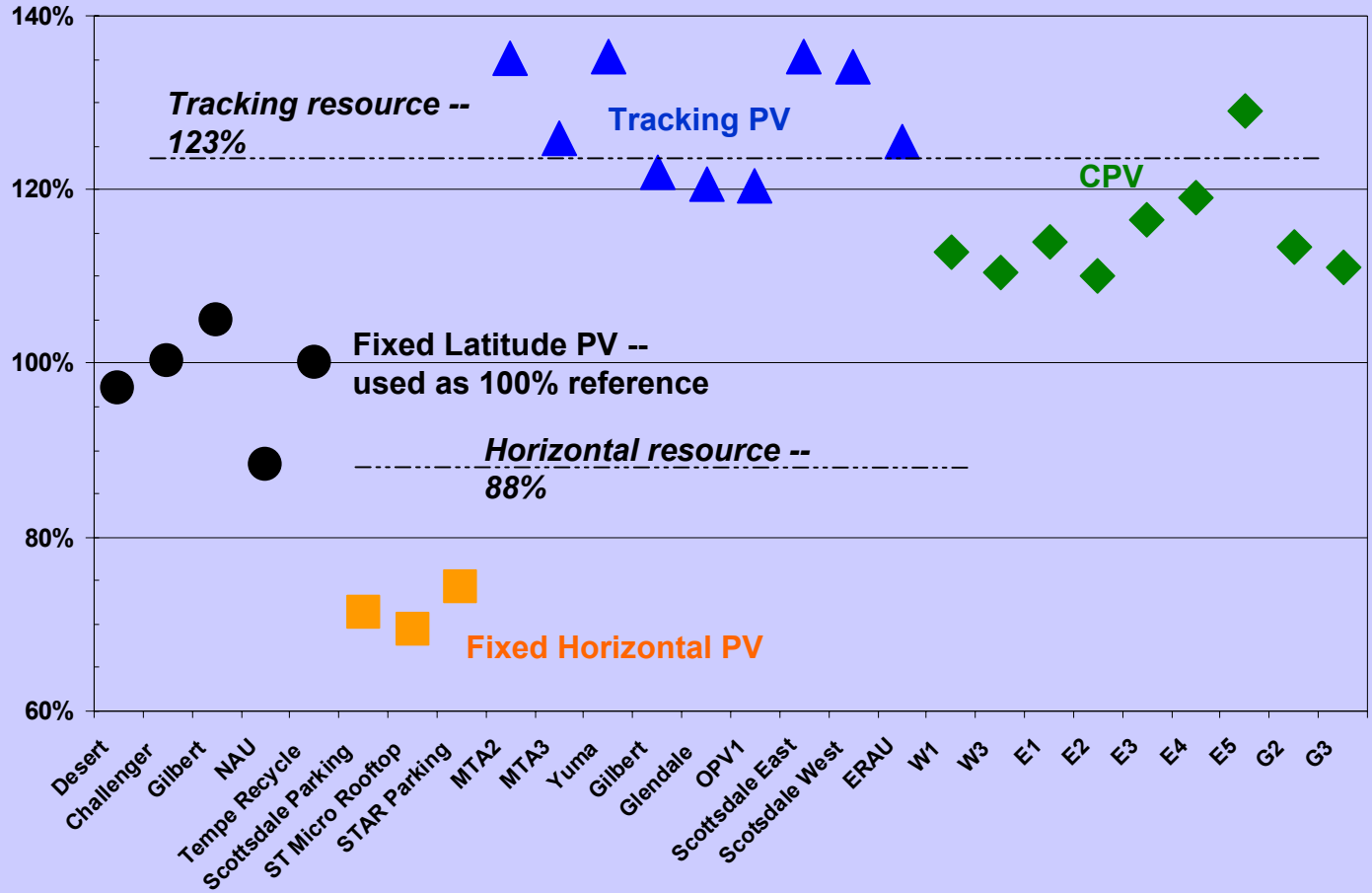
- Contractors are used for nearly all APS solar work
- Arizona companies have provided:
  - Engineering
  - Construction
  - Electronics and controls
  - Fabrication of steel -- including CPV prototypes

Solar kW Installed under APS Program



- Includes Customer kW program, excludes solar kWh credit purchases
- Includes 2004 PV construction underway
- 2005 includes 1 MW PV, plus 1 MW Solar Trough already in construction

2003 Solar Results -- kWh per kW Comparison

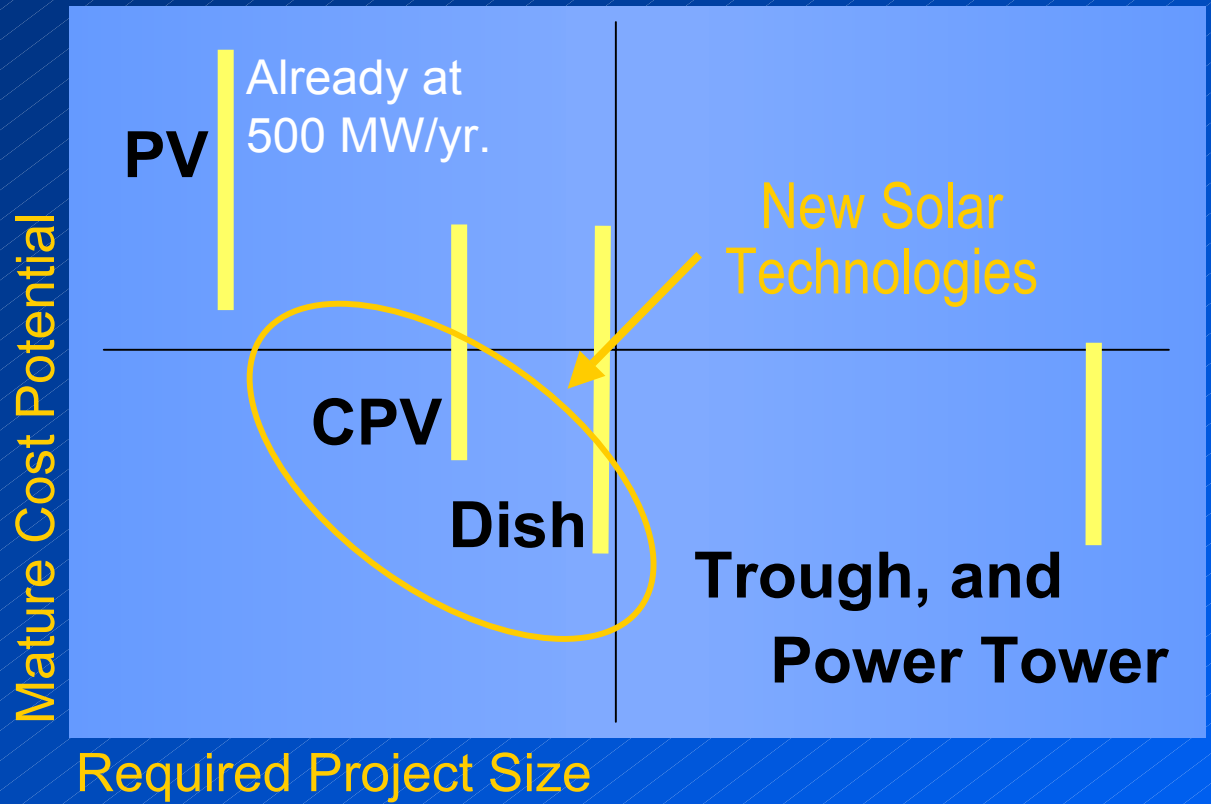


Ongoing Improvements in Trackers

- Annual output can be improved by tilting the PV modules on the tracker to the south

- First tilted-module tracker was recently installed at Prescott
- Some existing trackers will be retrofit for more output

New Solar Options -- Scale and Potential Cost



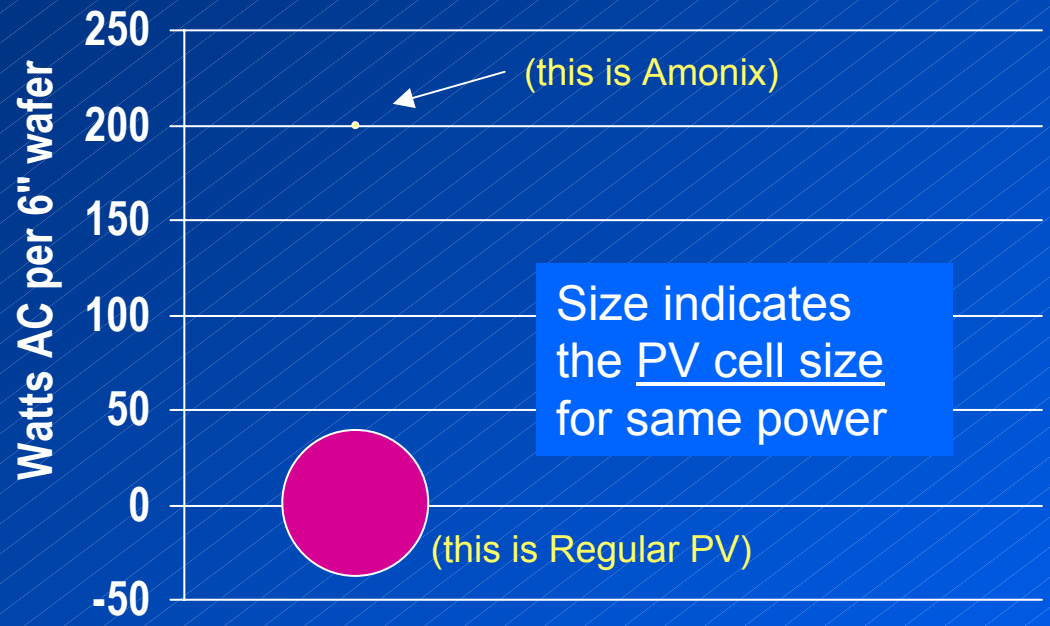
- Flat-PV is only technology currently made in volume
- Concentrators have low-cost potential, at moderate volume

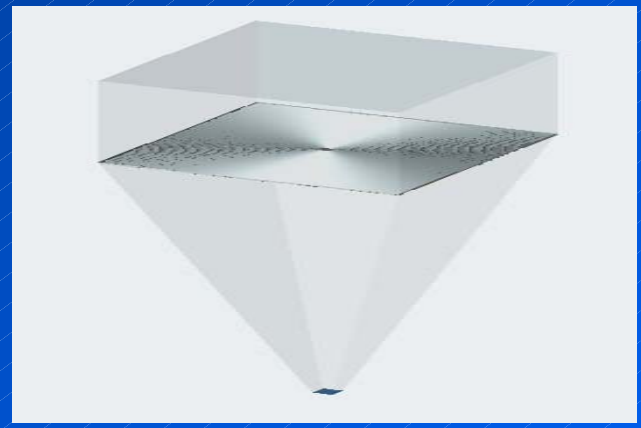
Concentrating PV Technology

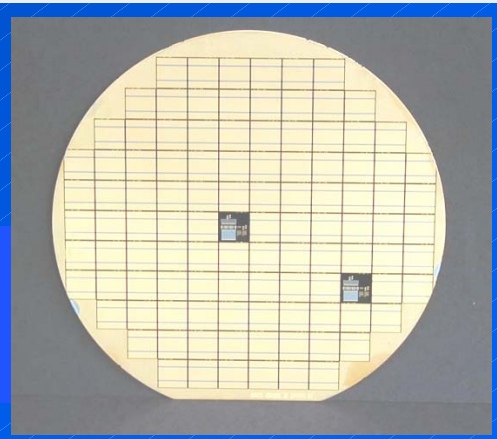
- 500 kW now installed for development and demonstration
  - Concentrating sunlight by 250x to 500x reduces cell cost
  - Amonix CPV cells are 26% efficient -- highest in world for silicon
  - New multi-junction cells can increase efficiency to over 40%

US southwest companies are currently the world leaders in CPV

Concentration of Sunlight Dramatically Reduces Cell Size







- CPV uses 1/300 the semiconductor size of regular PV
- PV cell efficiency goes up with concentration
- Less cell cost, and less environmental impacts

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CPV Benefits for the Southwest

- CPV is well suited for sunny, warm regions
- Local manufacturing is viable and advantageous for modules
- Silicon CPV can cost under $4/W AC ($3.40/W DC) at only 5 MW / year
- With efficiency improvements, costs can drop to $3/W AC ($2.55/W DC)

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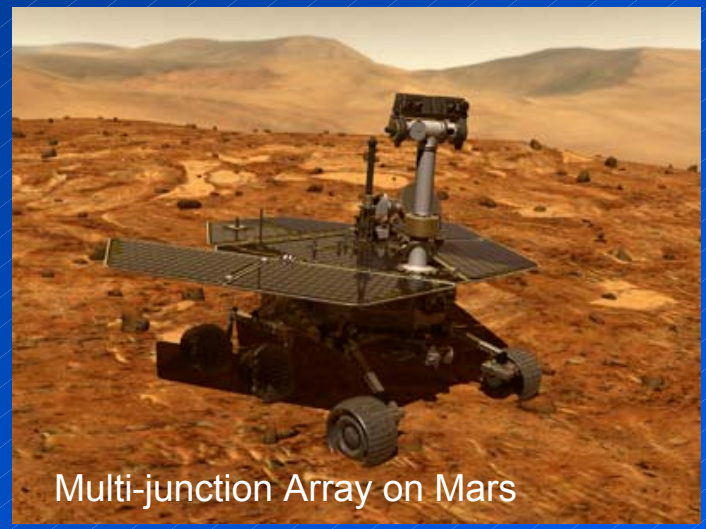
Recent CPV Advances

- First utility test of 32% efficient multi-junction cell at APS -- same technology now in use on Mars
- NREL installation of 25 kW Amonix unit, for testing and development
- NREL to support Arizona test of Spectrolabs multi-junction cell


Multi-junction Array on Mars


Multi-junction CPV at STAR


NREL Amonix at UNLV


Multi-junction Test Array

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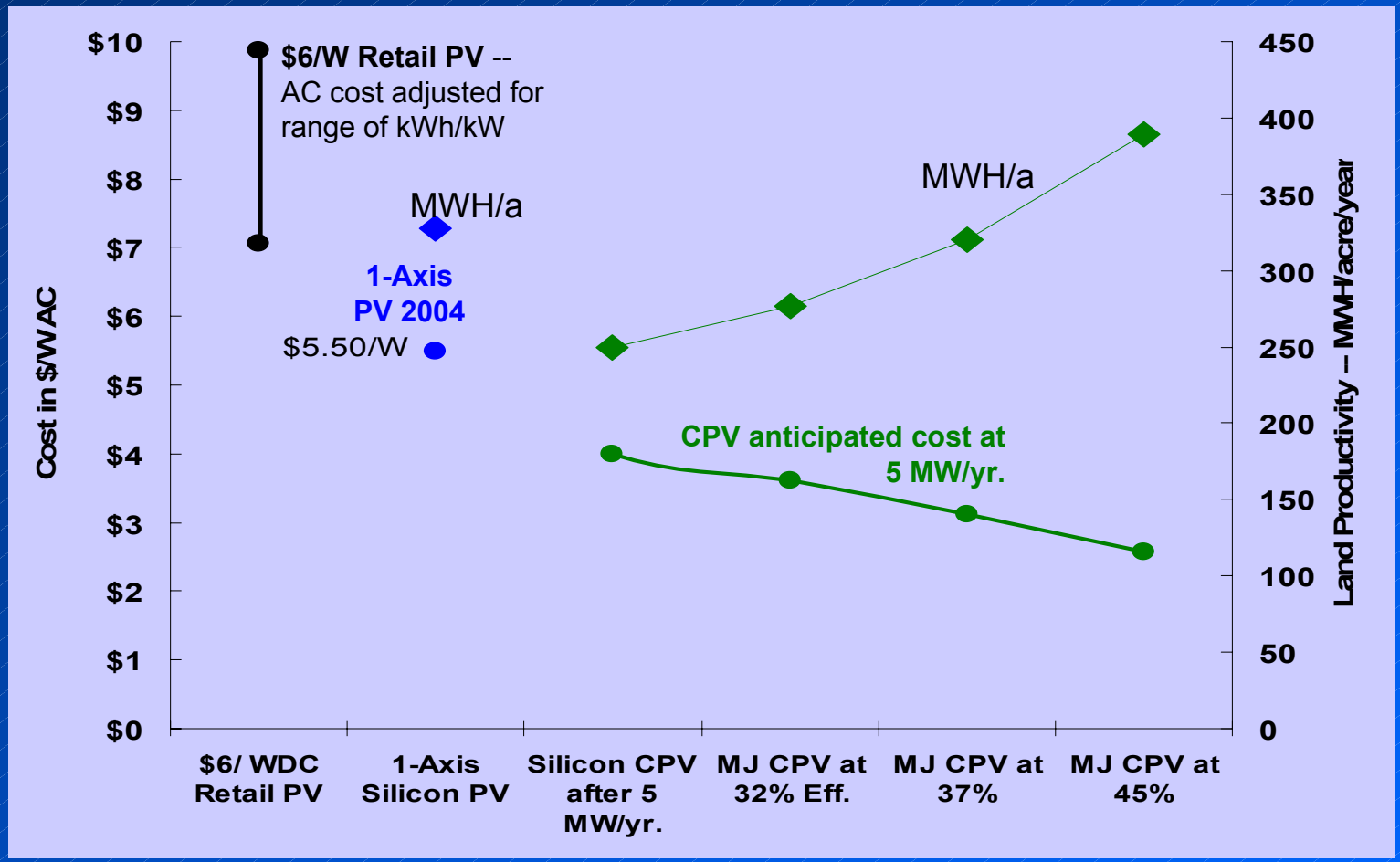
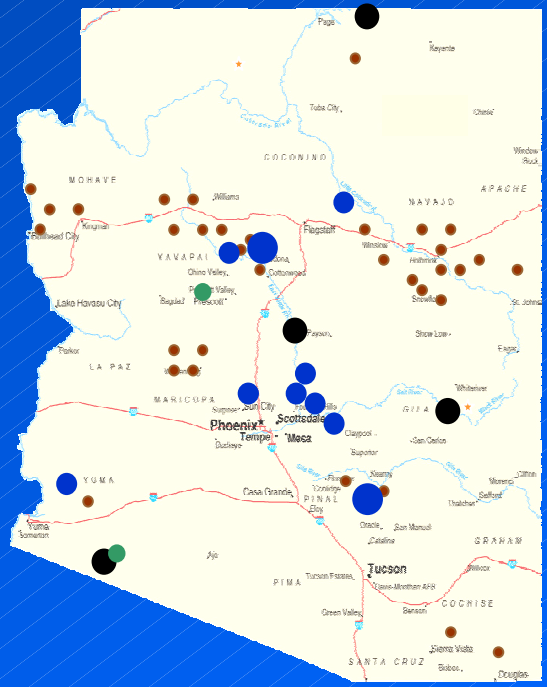
Estimates for Concentrating PV



- Conventional PV is currently over 500 MW/yr of volume -- 5 MW is 1%
- Many 100's of MW per year needed to meet SW regional goals

Arizona Solar Accomplishments with APS

- Rapid, sustainable growth in solar energy
- Largest utility off-grid solar electric service
- Solar Partners, the first solar-only green pricing, and largest utility PV rebate program in Arizona
- First large commercial single-axis tracking PV
- Largest High Concentration PV plant in the world -- over 500 kW
- First use of solar Dish to make and use hydrogen
- First solar thermal trough system since 1988



APS continues to advance the use of solar, in order to bring environmental and economic benefits to Arizona